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Bioflocculation of green microalgae using activated sludge and potential for biogas production

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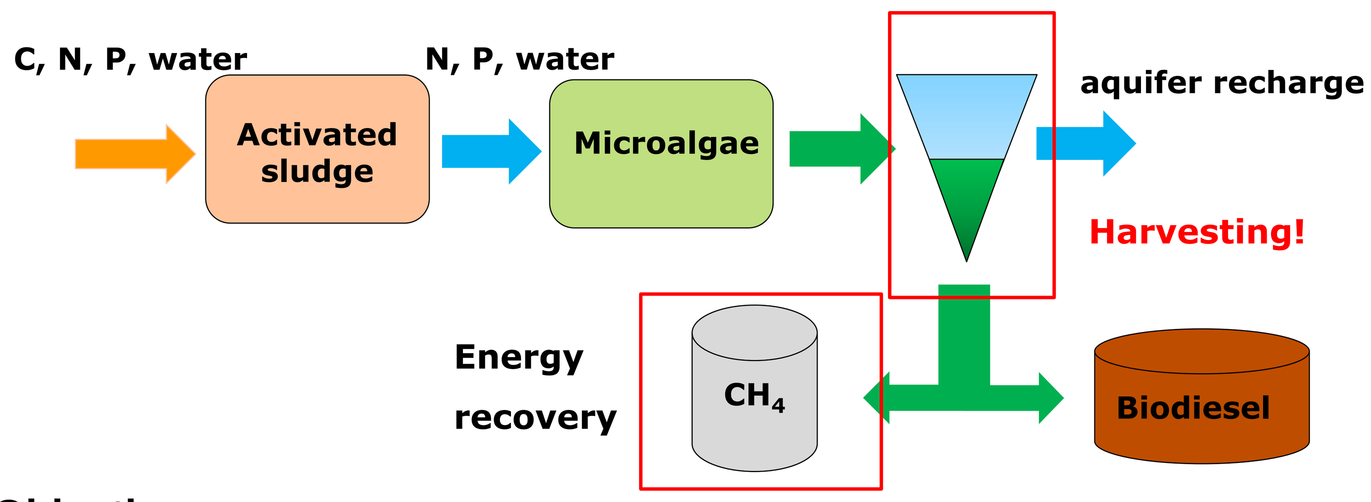
1. INTRODUCTION

New technologies are developed to recover wastewater resources and increase energy yields in form of biogas [1].

→ Potential energy recovery using microalgae.

Available harvesting methods are costly and energy intensive [2].



Objectives:

- Developing **cost-efficient** way of harvesting microalgae via **bioflocculation** using activated sludge from a short-SRT EBPR system.
- Assess the potential of **energy recovery** via **biogas production** from the harvested **activated sludge-algal biomass**.

2. METHODS

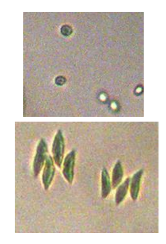
1. Flocculation experiments

Microalgal biomass:

Mixed green microalgal culture cultivated on effluent wastewater:

Chlorella sorokiniana

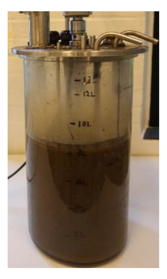
and *Scenedesmus sp.*



Activated sludge:

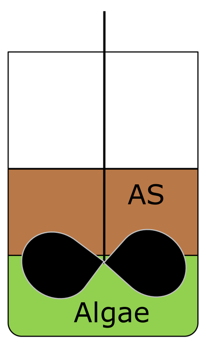
Taken from a short SRT (3.5 d) EBPR system [3]:

- Solid-liquid separation after the aerobic phase (AS_{AE})
- Solid-liquid separation after the anaerobic phase (AS_{AN})

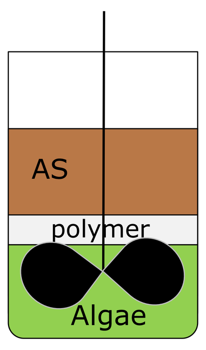


Flocculation strategies:

Strategy I:
Flocculation of microalgae and activated sludge



Strategy II:
Step 1: Coagulation of microalgae with a cationic polymer (PDADMAC)
Step 2: Flocculation with activated sludge



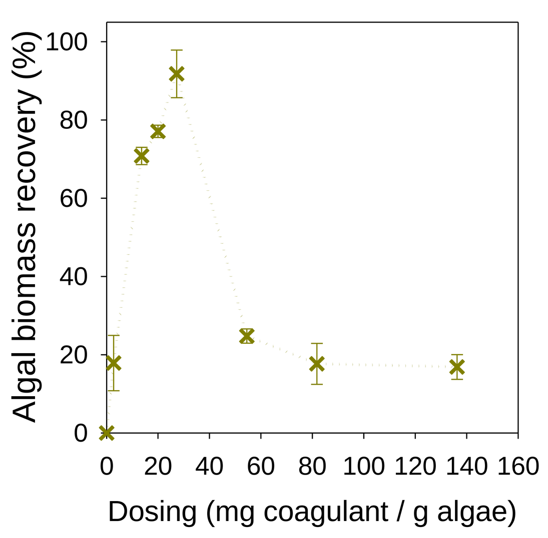
2. Biomethane potential tests

Mesophilic conditions (37 ºC)
Digestion scenarios:
I. Algae
II. Algae + polymer (20 mg/g algae)
III. AS_{AE}/AS_{AN} alone (activated sludge removed after the aerobic and after the anaerobic phase)
IV. AS_{AE}/AS_{AN} + algae (10% ratio of algae/AS)
V. AS_{AE}/AS_{AN} + algae + polymer (10% ratio of algae/AS, 20 mg polymer/g algae)

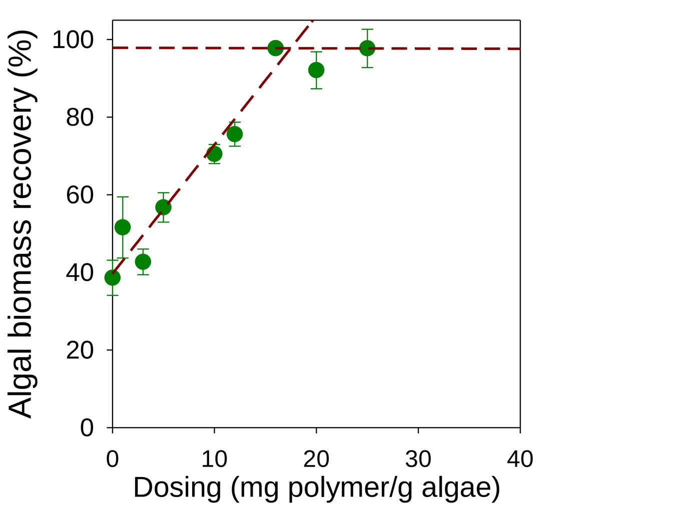
3. Flocculation

1. Polymer dosing

100% algae + polymer



10% algae + 90% activated sludge + polymer

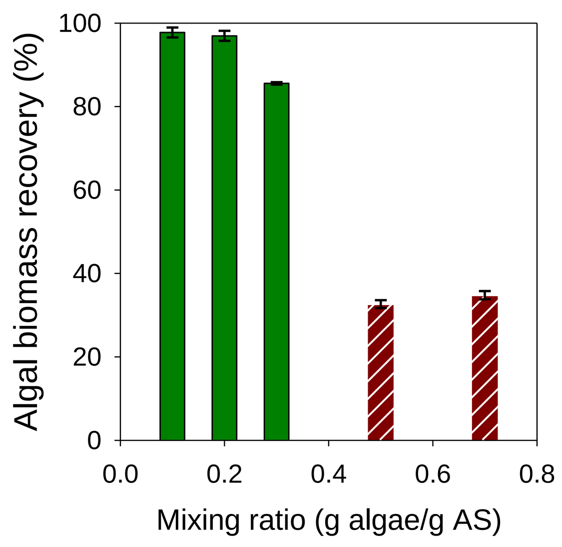


- **27 mg polymer/g algae** dosing results in **92 % microalgal recovery**
- **Restabilization effect** results in lower recovery at high polymer dosages

- **Microalgal recovery with activated sludge** used as flocculant (strategy I) **is low (40%)** → we need a coagulation aid (strategy II)
- **16 mg polymer/g algae** dosing results in **97 % recovery**

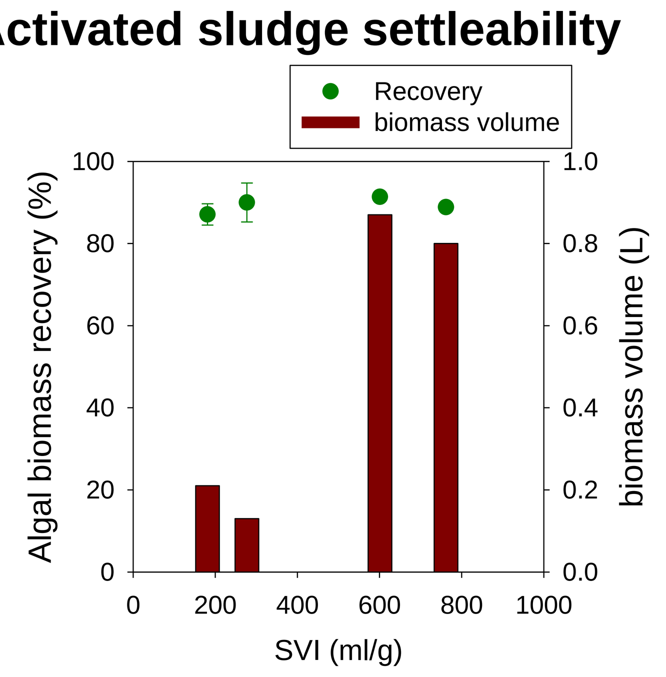
2. Mixing ratio

Algae + activated sludge + polymer (16 mg/g algae)



- With **increasing algae/activated sludge** ratios **more polymer dosing is required** to reach optimal recovery
- **Optimum dosing** should be **estimated for the specific operation conditions** of the process

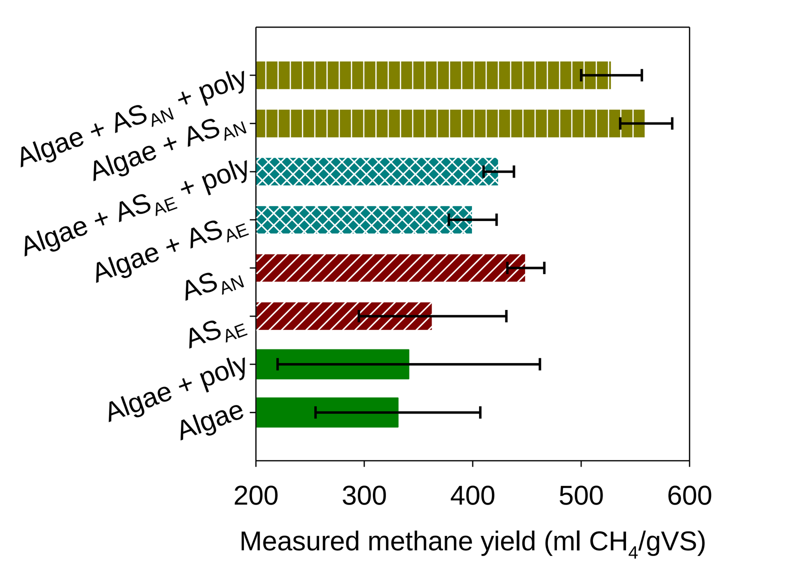
3. Activated sludge settleability



- Bulking events in activated sludge systems cause **poorly settling sludge** → The **biomass volume** after settling is **high**
- The **efficiency of the flocculation** does **not deteriorate**, the microalgal **recovery stays sufficient (>90%)**

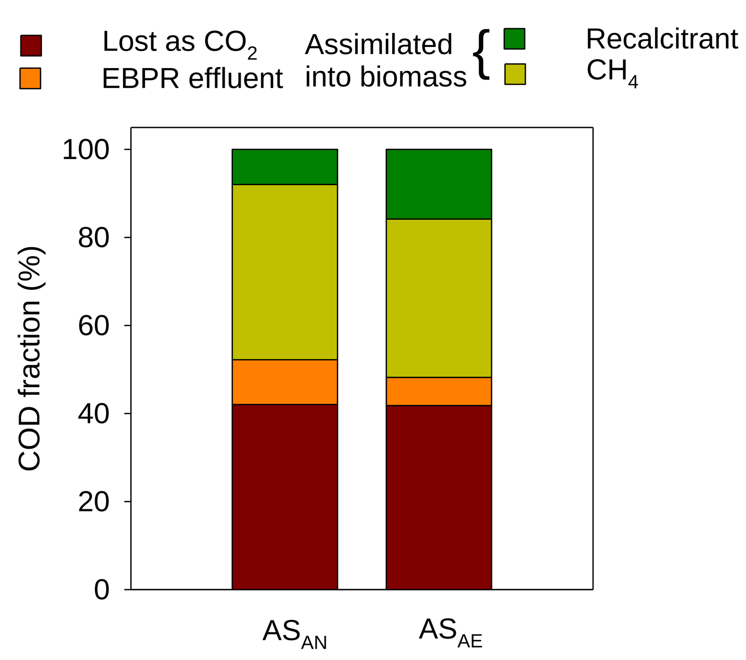
4. Biogas potential and energy recovery

1. Biogas potential of biomass



- **Co-digestion** of microalgae **with activated sludge removed** after the **anaerobic phase** produces **significantly higher** (P<0.05) **methane** than co-digestion of **activated sludge** taken after the **aerobic phase** → due to **stored PHA by PAO** in the anaerobic phase of the EBPR and **balanced nutrients** due to co-digestion with microalgae

2. Energy recovery



- Effective **preservation of organic carbon** via the EBPR→ **up to 40%** of the influent organic carbon is converted into methane
- Only **up to 10%** of the incoming COD is **lost to the effluent** of the EBPR

5. CONCLUSIONS

- An **effective** solution is proposed to **harvest microalgal biomass** and to significantly decrease the amount of polymer coagulant required;
- **97% microalgal biomass recovery** was reached with 16 mg polymer/g algae
- **Poorly settling** sludge did not affect microalgal biomass **recovery**, however, due to bulking the **biomass volume was increased**;
- **Optimum polymer dosing** depends on the **mixing ratio** of algae and activated sludge;
- **Co-digestion** with biomass taken after the **anaerobic phase enhanced biogas potential**;
- Up to **40% of the influent COD** of the EBPR **was recovered as methane**;
- Most of the **COD was assimilated into biomass or mineralized** to CO_2 and only up to **10% is lost in the effluent** of the EBPR.

ACKNOWLEDGEMENTS

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[1] Batstone, D.J., Hülsen, T., Mehta, C.M., Keller, J., 2015. Platforms for energy and nutrient recovery from domestic wastewater: A review. Chemosphere, 140, 2–11.
[2] Gerardo, M.L., Van Den Hende, S., Vervaeren, H., Coward, T., Skill, S.C., 2015. Harvesting of microalgae within a biorefinery approach: A review of the developments and case studies from pilot-plants. Algal Research 11, 248–262.
[3] Valverde-Pérez, B., Wágner, D.S., Lóránt, B., Gülay, A., Smets, B.F., Plósz, B.G., 2016. Short-sludge age EBPR process - microbial and biochemical process characterisation during reactor start-up and operation. Submitted to Water Research.